AIRCRAFT NOISE IN RESIDENTIAL AREAS - MEASUREMENT AND EVALUATION

H.-O. Finke and R. Martin

Translation of "Fluglärm in Wohngebieten - Messung und Beurteilung", Deutsche Gesellschaft für Luft - und Raumfahrt, Symposium über Triebwerkslärm, Braunschweig, West Germany, Feb. 20-21, 1974. Paper DGLR-74-013, pp. 1-8.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 AUGUST 1974

17

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT F-15,907		
4. Title and Subtitle AIRCRAFT NOISE IN RESIDENTIAL AREAS - MEASUREMENT AND EVALUATION		5. Report Date August, 1974
		6. Performing Organization Code
7. Author(s) H. -O. Finke and R. Martin		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw-2483
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Fluglärm in Wohngebieten - Messung und Beurteilung", Deutsche Gesellschaft für Luft - und Raumfahrt, Symposium über Triebwerkslärm, Braunschweig, West Germany, Feb. 20-21, 1974. Paper DGLR-74-013, ; pp. 1-8.

16. Abstract

Acoustical measurements and evaluations of aircraft noise were carried out by a team of university personnel in West Germany in the fields of acoustics, medicine, psychology, social sciences and occupational psychology. The Munich, West Germany airport was investigated in 1969. Inhabitants near the airport were tested by means of questionnaires, which were statistically evaluated.

(A74-27368)

PRICES SUBJECT TO CHANGE

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	

AIRCRAFT NOISE IN RESIDENTIAL AREAS - MEASUREMENT AND EVALUATION

H.-O. Finke and R. Martin

1. CONCEPT /1*

An interdisciplinary investigation of the effects of aircraft noise on man, sponsored by the German Research Association, has been carried out during the past years. The following questions were to be investigated:

- What sociological, psychological and physiological effects of aircraft noise can be expected, and under what conditions do they appear?
- In what way are the reactions to aircraft noise codetermined by influences of the social environment, or by psychic or somatic properties of the affected individual?
- In what way are the acoustic parameters of noise pollution related to the reactions of those affected?

The research team consisted of 6 sections:

- ACOUSTICS (H.-O. Finke, R. Martin/PTB [Physikalisch-Technische Bundesanstalt = Federal Physical-Technological Institute] Brunswick)
- MEDICINE (A.W. v.Eiff, L. Horbach, H. Joergens/University of Bonn)

---

* Numbers in the margin indicate pagination of the original foreign text.

- ORGANIZATION (B. Rohrmann/University of Mannheim)
- PSYCHOLOGY (R. Guski, H. Hoermann/ Free University, Berlin)
- SOCIAL SCIENCES (M. Irle, R. Schuemer-Kohrs/University of Mannheim)
- OCCUPATIONAL PHYSIOLOGY (G. Jansen/ University of Essen)

The research program was to complete the following steps in the vicinity of a large airport:

- social-scientific interviews with a standardized questonnaire in the homes of the test population
- psychomotor and psychophysiological experiments and tests in a research laboratory (approximately 2 hours)
- medical anamnesis, examination and physiological experiments in a research laboratory (approximately 2 hours)
- acoustic aircraft noise measurements in the entire test area (approximately 6-7 weeks).

The test area was to include a densely populated area near a large airport; in this area, aircraft noise was to be dominant over all other sources of noise.

During the last few years, the effects of aircraft noise have been researched also in other countries (England, France, the Netherlands, Japan, Sweden, the U.S., the U.S.S.R.). However, hardly any of these investigations started from an interdisciplinary viewpoint, i.e., investigating the same test population with teams of various professions.

Below we report on some partial aspects of acoustical measurements and evaluation, as well as on the correlation between physical parameters and selected reaction variables of the test population investigated [1,2,3].

2. TEST AREA

/2

The main research was conducted near the Munich-Riem airport in 1969, following detailed, methodical preparations and a preliminary study near the Hamburg airport. Using test measurements, the area was narrowed to one in which the average A sound level due to overflights exceeded 75 dB. This area covers approximately 30 km^2 and has a population of over 100,000. The average daily number of overflights near the airport was approximately 80 (2/3 takeoffs, 1/3 landings) and the average A sound level of the flights over the test area ranged from 75 to 107 dB. To keep area-characterizing acoustic measurements to a minimum, a group of houses or apartments was combined into a so-called cluster; the characteristic acoustic value of the measuring site at the cluster's center was then assigned to all members of the test population living in surrounding dwellings.

Several concepts are possible to select the clusters that will characterize the entire test area as random samples, depending on whether actual population density or varying aircraft noise pollution were to be represented. Figure 1 illustrates two possible models: on the left half, clusters are distributed evenly, as random samples, throughout an area limited by an external noise contour. A certain percentage of the population is thus incorporated into the random sample, regardless of the noise level associated to it. Due to the high level gradient in the vicinity of airports, the portion of the population exposed to high noise levels will be underrepresented. According to a different concept (right half of Figure 1), the random sample density increases towards the louder areas near the airport; due to this, the percentage included in the random sample increases at higher noise levels. Within the random samples, all noise levels are equally represented. The type of model chosen has important consequences for data interpretation and conclusions applied to total population.

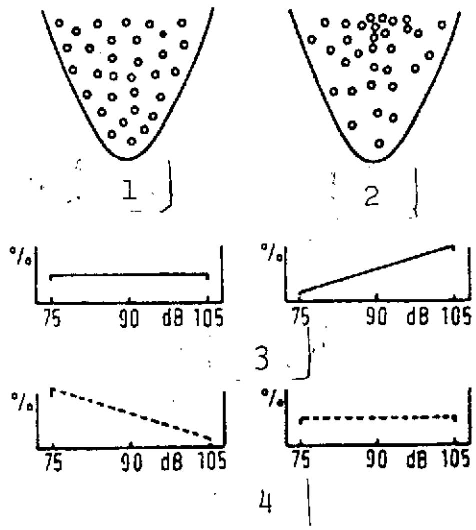

Figure 1. Cluster distribution in the test area:
two models

(1) Random Sample (2) Test sample concentrated inward

(3) Percentage of actual population selected

(4) Portion of population included in the random or test sample

The known, large aircraft noise investigations have used the first, or a mixture of both concepts; the Munich investigation used a refined, 32 level version of the second concept.

An acoustic measuring site is established in each of the 32 fixed clusters. The individuals interviewed (approximately 30 per cluster) lived within a radius of approximately 100 m of the measuring site and hence the acoustic situation was similar. It could be described by means of the characteristic value for the measuring site, and attributed to everyone in the cluster.

3. ACOUSTICAL MEASUREMENTS

/3

The following quantities were expected to characterize the acoustical situation: the maximum A sound levels of the overflights (L_A), the number of daily overflights (N), various durations and frequencies, as well as characteristic values for background noise, for both day and night.

In principle, the noise pollution near airports can be calculated from emission measurements and calculations [4] and valid flight schedules, or from the known noise levels of all airplane models and current or future overflight frequencies (for instance, as is done for noise protection ranges). For studies of the kind here reported, however, actual noise pollution is determined by long time measurements at the time of the investigation and by interviewing the sample population.

It was necessary to establish 32 measuring sites for the 32 clusters in the test area. Twelve measuring stations were built and cyclically replaced at the measuring sites, on a daily basis. The measuring stations operate on batteries and automatically. Measurement values were stored on magnetic tape and were read out at the laboratory from level recordings. Measurements covered a 7 week period and yielded approximately 400 useable tapes with nearly 21,000 recorded overflight instances. Magnetic tape instruments with maximal recording times of 3 hours were available to cover a full 24 hour measuring day. This limitation in the recording capacity required the following recording procedure:

- using acoustic switches with regulable sound thresholds (70 - 90 dB) only instances exceeding certain minimum levels (overflights) were recorded;
- only random samples were taken of the background noise, at certain intervals (4 s recording, 56 s pause; ratio 1:15),

since its average value changes only slowly;

- a timer started the tape instrument every hour on the hour, placing a time marker on the tape as otherwise only the sequence but not the actual time of the overflights could be evaluated, due to the discontinuous tape operation.

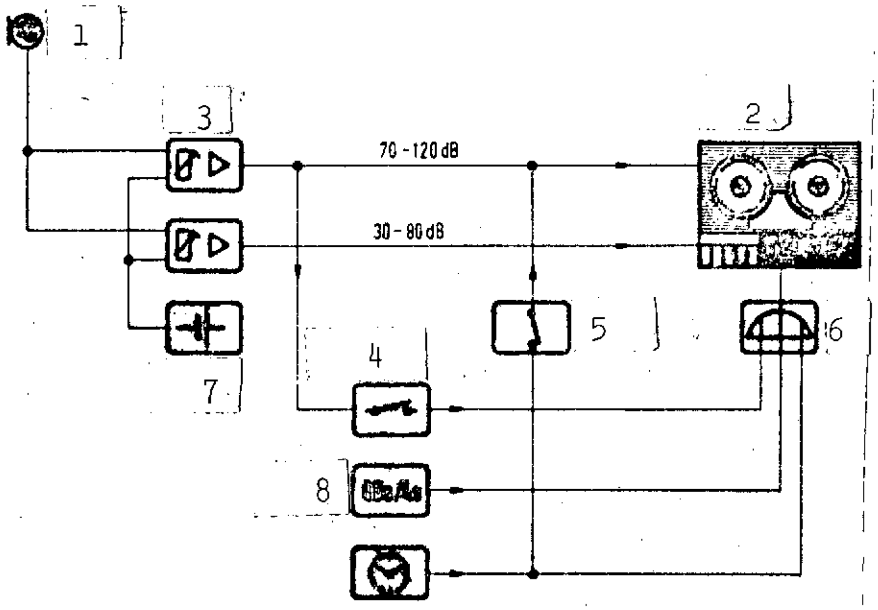

Figure 2. Measuring station block diagram

(1) Microphone
(2) 2-channel tape instrument
(3) Amplifier
(4) Threshold value switch
(5) Time signal
(6) Start
(7) Batteries
(8) Timer switch

Division of the measurement range into two channels, each /4 encompassing 50 dB, was required to cover the wide level range from 120 dB for the highest overflight level down to the 30 dB background level at night. The mechanism was enclosed on all sides by a metal housing, with the microphone protruding on a flexible metal hose.

4. EVALUATION

After recording the magnetic tapes, the levels, durations and frequencies of overflights, as well as background noise data as individual measurements were available for all measuring sites, classified and appropriately averaged. Figure 3, for instance, shows the relationship between level and duration during one day of measurements for one measuring site near the airport and one displaced to one side of it. Additional evaluations were performed using different time constants on the recorder (impulse, fast, slow) and frequency analyses, and also as addenda to the results of other investigations. Table 1 shows the differences in maximum overflight noise levels for various instrument time constants at two distance ranges.

A variety of influences, investigated individually, became apparent already during the preliminary investigation; one example is the influence of microphone height [5]. Frequency analyses identified tonal portions that are clearly audible and whose pitch changed in the course of the overflight. They are caused by interference between the sound picked up directly by the microphone and that reflected by the ground. Figure 4 shows narrow band analyses (at left) and sound spectrograms (at right) of one overflight, simultaneously recorded with three microphones at different heights.

This effect can become active in calculation procedures /5 that derive additions for tonal portions from the spectrum (Effective Perceived Noise Level). Interference effects have no influence on the total noise level.

A number of characteristic values for different international methods of describing aircraft noise (CNR, NEF, NNI, $\bar{Q}$, etc.) can be calculated from acoustical parameters. All values

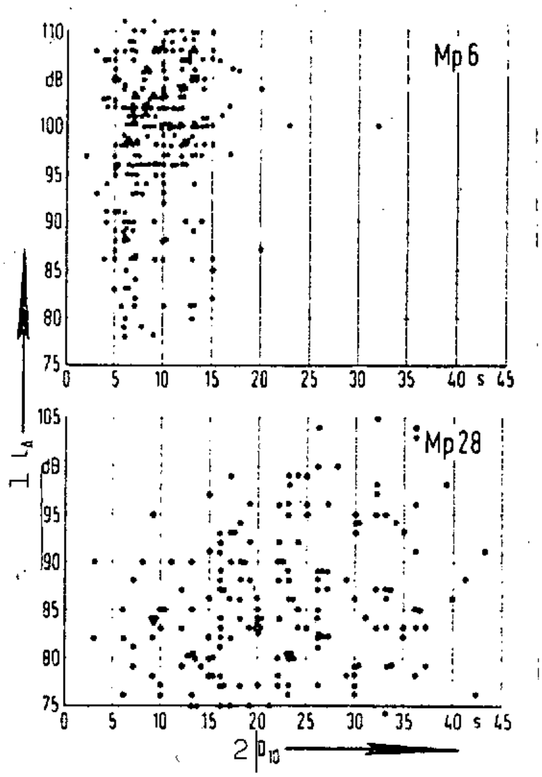

Figure 3. Distribution of level and duration at measuring sites near the airport (top) and farther away from it.

(1) Overflight level (2) Overflight duration

TABLE 1. AVERAGE DIFFERENCES IN THE A-NOISE LEVEL FOR DIFFERENT TIME CONSTANTS OF THE INDICATING RECORDER

	Measuring site to airport distance	
	1 - 2 km	5 - 10 km
$L_{AI} - L_{AF}$	1.8 dB	1.3 dB
$L_{AF} - L_{AS}$	2.2 dB	2.0 dB

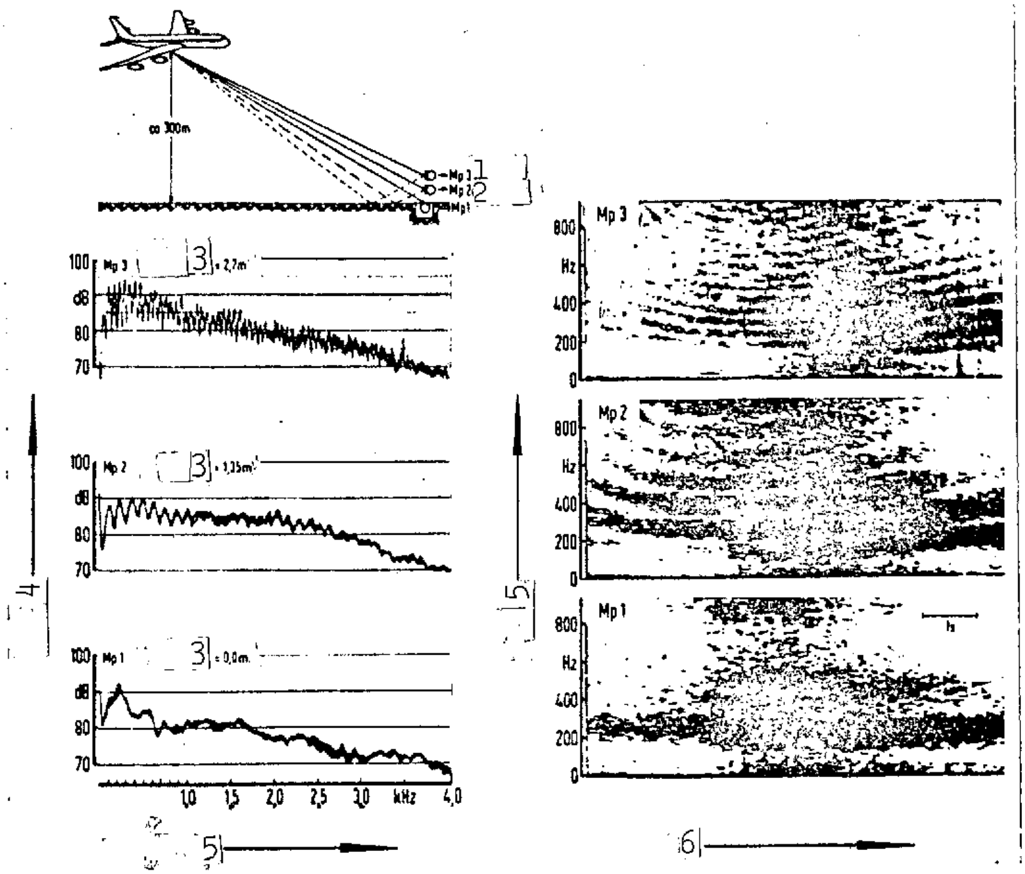

Figure 4. Analyses of overflight noise recorded at three different microphone heights (0 m, 1.37 m, 2.70 m)

(1) 2.7 m high
(2) 1.35 m high
(3) Microphone height
(4) Band level
(5) Frequency
(6) Time

were correlated with each other and with the results of the other sections. It became possible to optimize an aircraft noise evaluation measure FB1 empirically, without anticipating the weighting of individual parameters. It achieved its maximum correlation with the nuisance variables and has the following structure:

where L_{Ai} is the A noise level of the overflight and N the number of daily overflights.

Its structure is simple and it contains only parameters that also correlate highly with nuisance values on an individual basis.

Figure 5 shows the correlation between some characteristic values and the "total nuisance" (see below) determined by social science methods. L_A is the arithmetic average of A noise levels, $\overline{Q}$ corresponds to L_{eq} according to the law for protection against aircraft noise (q=4); L_{eq} is the equivalent continuous noise level according to DIN 45,641, NNI is a characteristic value used in England, L_S -- except for an additive constant -- is identical with a French (R,N) and an American (CNR) procedure. /6

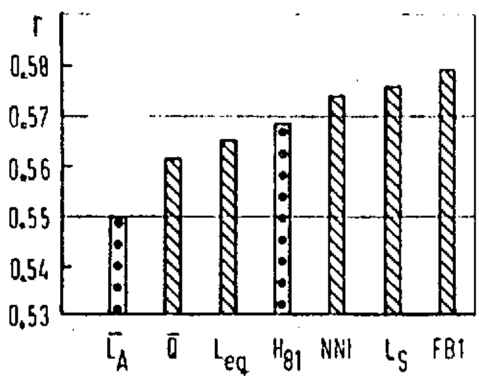

Figure 5. Correlation coefficients of some characteristic values with nuisance

Figure 6 shows the correlation between nuisance and the equivalent continuous noise level for equivalence parameters q = 1 to q = 10. For q = 3 the value represents the energy equivalent continuous noise level and q = 4 the nuisance index $\overline{Q}$ (or L_{eq}, according to the law for protection against aircraft noise).

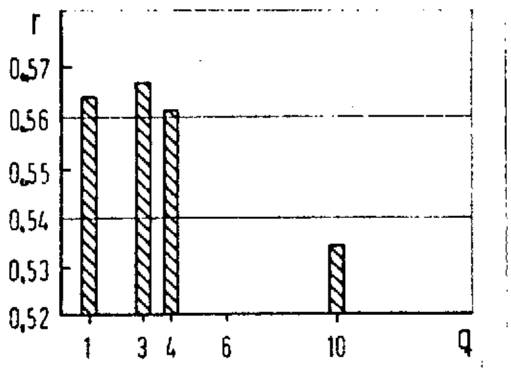

Figure 6. Correlation coefficient between the equivalent continuous noise level and nuisance (for different equivalence parameters q)

The characteristic values correlate to 0.97 among each other, meaning that as physical predictors they are nearly equivalent to subjective nuisance.

5. SOME RESULTS OF THE INTERDISCIPLINARY EVALUATION

The interdisciplinary evaluation established the connections for each individual of over 100 data sets in the final evaluation using multi-variable procedures, including correlation, factor and discriminance analyses.

Data from the Social Sciences Section, for instance, showed that with increasing aircraft noise (as expressed by FB1, correlation between parentheses):

- Interference with communications (conversation, radio, TV) increases (r = 0.56);
- interference with rest and relaxation increases (r = 0.39);

- attachment to the area decreases ($r = 0.51$); and
- aircraft noise is mentioned more frequently and spontaneously as a nuisance ($r = 0.35$).

From the total of 11 reaction variables, factor analysis led to one factor for the overall annoyance with or concern about aircraft noise. The correlation coefficient between this annoyance and the aircraft noise evaluation measure FB1 was $r = 0.58$. All of the indicated correlations were calculated using the values for individual members of the test population; if these individual values are averaged for each cluster, then the correla- /7 tions become much higher due to the reduction in data dispersion. In that case, the correlation between annoyance and FB1 reaches the value $r = 0.87$.

A correlation of $r = 0.57$ between physical irritation (FB1) and subjective reaction (annoyance) indicates that $r^2 = 0.34$, i.e., 1/3 or 34% of the annoyance due to aircraft noise is determined by acoustical data. This correlation can be improved taking into account another group of variables, the so-called moderator variables (predominantly personality characteristics such as adaptation to noise, status, conservatism, or environmental conditions such as length of residence, and such); these variables do not correlate with the aircraft noise parameters, but do correlate with the annoyance. If these variables are included (23 in this investigation, or 4 after factor analysis), then the determination of the annoyance can be increased to almost 70%.

The results of the medical examinations of the test population did not establish any significant connection between identifiable incidences of illness and the degree of aircraft noise. Nevertheless, aircraft noise as a risk factor for certain areas, such as essential hypertonia, could not be ruled out.

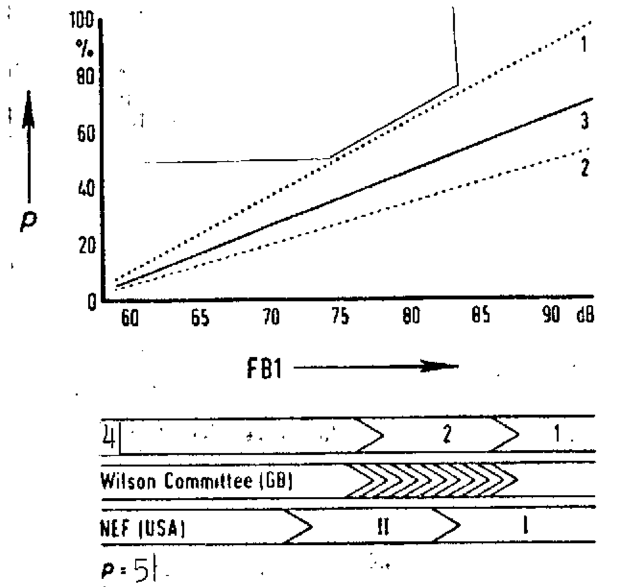

Figure 7. Effect of aircraft noise as a function of FB1 and limiting values for noise protection ranges

(1) Interference with communications (2) Interference with rest and relaxation (3) Aircraft noise as irritant (mentioned spontaneously) (4) Aircraft Noise Law of the FRG (5) Percentage of individuals affected

A "defensive reaction" was determined by the psychophysiological experiments; it can be interpreted approximately as blocking of the information reception process. Its correlation with the degree of aircraft noise (FB1) is r=0.21.

All correlations between aircraft noise and reaction to it proved to be linear; this makes it impossible to derive "critical limits" for tolerance or expectations. Characteristic acoustical values such as level, at which a certain percentage of the population shows a certain reaction (such as 80% in communications disruption), achieves different levels for different reactions. Figure 7 illustrates, as an example, regression lines for three reaction variables over the acoustic stimulus FBl. Noise protection ranges are plotted below the abscissa axis, as established in the FRG, England and the U.S.

Table 2 compiles the population, percentage of those whose /8
communications and rest are interfered with (in the random sample) and the total number of those affected in each area, for four sub-areas (Aircraft noise increasing from A to D):

TABLE 2. RELATIVE AND ABSOLUTE NUMBER OF PERSONS AFFECTED IN THE PARTIAL AREAS

Aircraft noise area	A	B	C	D
Population	45,000	44,000	15,000	2,000
FBl (dB)	65.1	74.6	82.7	90.8
Affected, rel.	21%	43%	56%	70%
Affected, abs.	9,400	18,900	8,400	1,400

The detailed final report on methods, results and consequences will be published subsequently as:

"DFG-Forschungsbericht: Fluglaermwirkungen - eine interdisziplinaere Untersuchung ueber die Auswirkungen des Fluglaerms auf den Menschen" [German Research Association Research Report: Effects of Aircraft Noise - an Interdisciplinary Investigation of the Effects of Aircraft Noise on Man] (with English summary), Bonn 1974

REFERENCES

1. Finke, H.-O.; Guski, R., Rohrmann, B., Schuemer, R. and Schuemer-Kohrs, A.: An Interdisciplinary Study on the Effects of Aircraft Noise on Men. International Congress on Noise as Public Health Problem, Dubrovnik, May 1973.

2. Martin, R., Rohrmann, B. and Finke, H.-O.. Psycho-Acoustic Results of an Interdisciplinary Study on Effects of Aircraft Noise on Man. Inter Noise 73, Copenhagen, August, 1973.

3. Finke, H.-O. and Martin, R.. Messung und Beurteilung der Geraeuschbelastung in der Naehe eines Flughafens [Measurement and Evaluation of Noise Pollution near an Airport]. DAGA '73, Aix la Chapelle, September, 1973.

4. Finke, H.-O. and Bostelmann, H.: Schallpegelmessungen an Duesenflugzeugen [Noise Level Measurements in Jet Aircraft]. PTB-Mitteilungen (1965), No.1.

5. Finke, H.-O. and Martin, R.: Fluglaermmessungen in Wohnbebieten [Measurement of Aircraft Noise in Residential Areas]. Kamp dem Laerm (1970), No.1.

Translated for National Aeronautics and Space Administration under contract No. NASw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.